COMMUNICATION BETWEEN A MULTICHANNEL AUDIO ACQUISITION AND AN INFORMATION SYSTEM IN A HEALTH SMART HOME FOR DATA FUSION

Dan Istrate, Gilles Virone, Michel Vacher, Eric Castelli, Jean-François Serignat

COMMUNICATION BETWEEN A MULTICHANNEL AUDIO ACQUISITION AND AN INFORMATION SYSTEM IN A HEALTH SMART HOME FOR DATA FUSION

Dan Istrate[1*], Gilles Virone[2**], Michel Vacher[1], Eric Castelli[3] and Jean-François Serignat[1]

[1]*CLIPS-IMAG laboratory UMR CNRS-INPG-UJF 5524, Team GEOD 38041 St Martin d'Hères Cedex, France*
[2]*TIMC-IMAG laboratory UMR CNRS 5525, Team AFIRM, 38706 La Tronche Cedex, France*
[3]*International Research Center MICA, 1 Dai Co Viet - Hai Ba Trung, Hanoi - Vietnam*

Abstract

The Health Integrated Smart Home Information System (HIS²) has been developed in the TIMC laboratory for the remote monitoring of the health status of an elderly person during daily life at home. This aims at improving patients' life conditions and at reducing the costs of the long hospitalization. The design of this system is based on a CAN network linked to volumetric, physiological and environment sensors. In addition, a collaboration between the TIMC and the CLIPS laboratories permitted to replace the video camera, not well accepted by the patients by a system based on a multichannel Sound Acquisition. The coupling between both systems will enable to detect if the person is in a situation of distress or not. Both systems locally processe in real time the incoming data and communicate using a CAN network to display the health status. This article describes the system architecture of both systems, practical solutions for their communication and the evaluation results.

Key Words

CAN network, smart sensors, audio processing, audio recognition, health monitoring, home automation.

1. Introduction

The proportion of the world's population of individuals over the age of 60 is expected to double by 2030 and to reach twenty percent of population. Besides, a large proportion of elders lives alone and are limited by chronic conditions or disabilities. Such observation demonstrate need for methods to monitor the health of elders in a way that caregivers are advised of any potential problems in the future.

Residential institutions providing social and healthcare services are a convenient solution, but such organizations are unrealistic at home. Moreover, most people who live there cannot adapt to the group environment and with the increasing demand, vacancies have become rare, causing some elderly to be shifted from one place to another, and this instability can also increase the morbidity. In conclusion, many elderly people understandably prefer to continue living at home.

To envisage the stay at home of such populations, the concept of "Health Smart Homes" (HSH) has been worked out in many laboratories and several experiments are taking place currently [1]-[3]. Different research teams have developed their own medical, technical and ethical specificity's to alert the medical providers. One of the originality of the HIS² presented in this article, is to replace the monitoring video cameras by a system of multichannel sound acquisition charged to analyse in real time the sound environment of the home in order to detect abnormal noises (call for helps or moans). This audio system is interpreted as a single smart sensor for the HIS². This paper presents the hardware and software structure of both systems with the integration of the audio system in the HIS².

2. Material and methods

2.1. The experimental plate-form HIS

The Health Integrated Smart Home Information System (HIS²) is a 30m² experimental platform (a two single rooms apartment) for the evaluation and the development of technologies in order to ensure the security and quality of life for patients who need home based medical monitoring (fig. 1) [4]. It integrates smart sensors (volumetric, audio, physiologic, environmental, etc.) linked to a master PC via a CAN bus [5]. Depending on the type of sensors (physiological, activity, environmental or microphones), we use the appropriate mean (Table I) to establish the connection. The eight microphones for audio surveillance are linked to a slave PC and can be interpreted as a single smart sensor as a whole.

Location and audio sensors are placed in each room of the HIS², allowing the monitoring of the patient's successive position and sound activity within the patient's home environment.

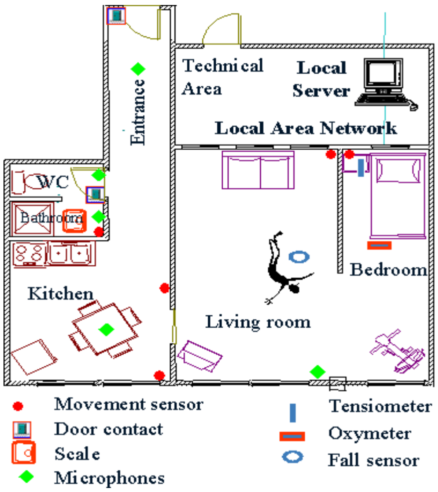


Fig. 1. The HIS².

2.2. Architecture of the monitoring system

2.2.1. The communication network

The sensor data is sent on the CAN fieldbus whose standard is ISO 11898, a serial bus [6]. We chose this fieldbus because it increases the security on the network. Indeed, it is enclosed within the platform and not directly open to the outside as an ethernet connection would be. Secondly, it implements a Producer-Consumer model. Each sensor on the CAN network can communicate with any other device using a deterministic response at its own rate, in opposition with the Ethernet network. This propriety to share the information among all sensors follows the "Information-Diffusion" model.

TABLE I

Communication, ID and Priority of the Sensors

Sensors	ID	Priority	Communications
Actimeter	1	1	RF module
Oximeter	4	2	RS232 serial link
Tensiometer	5	3	RS232 serial link
Information Audio	6	4	CAN Fieldbus
Scale	7	5	RS232 serial link
Volumetric sensor	8	6	Logic I/O
Thermometer	10	7	Analog port
Luxmeter	10	7	Analog port
Hygrometer	10	7	Analog port
Effectors	11	8	Logic I/O
Sound file	512	9	CAN Fieldbus

Each data frame transmitted on the bus by a node (the sensor) is endowed with the identifier (ID) of the sensor corresponding to the node where it comes from. All the nodes on the bus receive the message and can decide to exploit it according to its ID. This functionality enables us to add or remove sensors easily on the bus in a "Plug and Play" manner. In a collision case, the bus gives a deterministic response, the most priority node wins the bus. The smaller the ID, the higher the priority will be. We associated high priority to the sensors that can signal emergency situations (fall in the home, etc.) (Table I).

An embedded electronic board was designed to connect the different systems (sensors and actuators) located in home and to link them on a CAN bus. This board is 3 per 3 inches wide and battery powered (power supply @ 6V/30mA). It processes the data locally (smart devices) using the following main chips:

- An 8-bit RISC microcontroller (AT90S8535, ATMEL) that performs signal acquisition, computing, signal processing and data communication management.
- A CAN protocol controller (SAE81C91, Siemens) that encapsulates the data into frames according to the CAN protocol, and manages the data transmission.
- A CAN-Transceiver (PCA82C250N4, Philips) that adapts the data stream to the wired network.

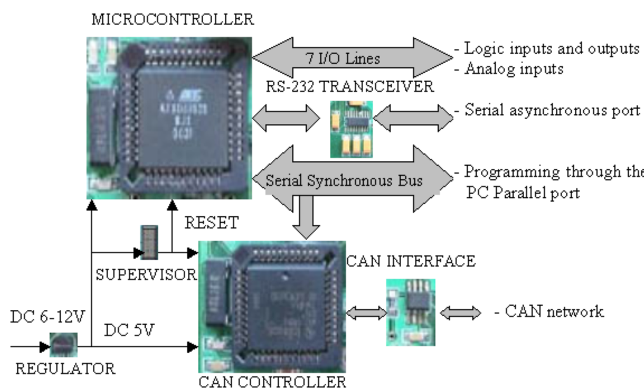


Fig. 2. The CAN adaptation Block Diagram.

The board provides the following communication elements (fig. 2):

- 8 logic I/O for Boolean status and actions.
- 8 analog inputs with a 10^{-3} resolution (1024 points).
- A serial asynchronous port (RS232).
- A serial synchronous data link (SPI).
- A RF module in the ISM band (434/868MHz).
- CAN Fieldbus Access.

The microcontroller accesses the CAN controller registers through the serial synchronous data link (SPI), as shown in figure 2.

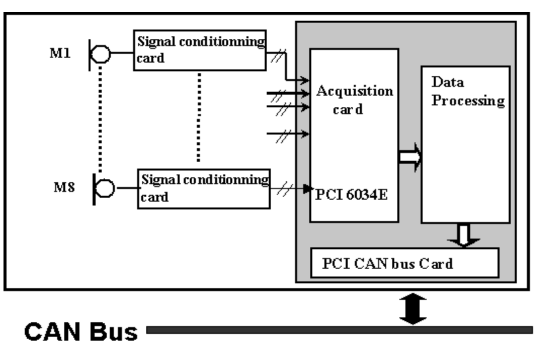
2.2.2. The master PC

The master PC is in charge of receiving the data from the CAN network. It communicates with the network through the National Instruments PCI-CAN/2 board plugged into its PCI bus. Then, a monitoring application (the Supervisor), implemented using LabWindows/CVI™, which is an interactive ANSI C programming environment tool, can use different methods of a ready-made objects library to access the CAN bus. Since we need to transfer arbitrary CAN frames, we chose to use the CAN Network Interface Objects to encapsulates the CAN port of the PCI interface. This makes it easy to read and write complete CAN frames on the network. When frames arrive over the network, they are placed into the read queue of the CAN Network Interface Objects. Then we can retrieve them by using the "ncCreateNotification" polling function. This function creates a notification callback where we process the messages.

2.2.3 The slave PC

The smart audio sensor contains 8 microphones (5 actually used), 8 signal conditioning boards and a data acquisition board (see the figure just below).

The used microphones are omni-directionals, condenser type, of small size and low cost. The signal conditioning card, associated with each microphone, consists of an amplifier and an anti-aliasing filter. The acquisition is made by a multi-channel National Instruments acquisition card PCI 6034E (8 differential channels). The acquisition is made at a sampling rate of 16 KHz, a frequency usually used in speech and audio applications. In order to drive in real time the data acquisition board we have used the low-level functions [7]. After digitalization, the sound data is either saved in real time on the hard disk of the host PC, or analyzed.



When a sound event is detected, the smart audio sensor sends a frame of information on the CAN bus. The frame contains: date and time detection (day, month, year, hour, minute, seconde, milliseconds), a flag to indicate the type of sound event (speech or noise) and a character field. This character field is composed by: the three most probable noise classes (or words) with their corresponding likelihoods and the localization of the sound event (the room).

3. Results and discussions

3.1. Health status monitoring

A series of tests have been elaborated to validate the hardware and software implementations. We took measures of all the sensors implemented in the HIS. The transfer for the physiological sensors is performed on demand when the user presses a push button. The CAN board polls the detection sensors states and only deliver a new frame on the CAN bus when a new state is evaluated [8]. The supervisor constantly displays and interprets the most recent physiological data collected (weight, blood pressure, S_aO_2, activity, environmental conditions, etc.) including the sound (fig. 3) to trigger alerts in case of emergencies. For example, fall in the home, chronic disease symptoms as nycturia, pollakiuria, etc.

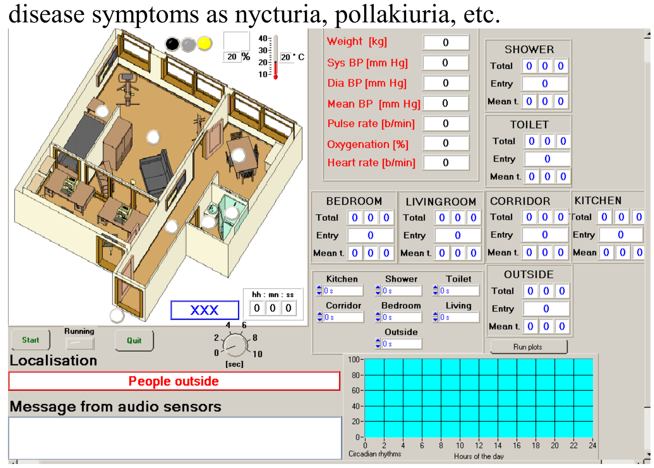
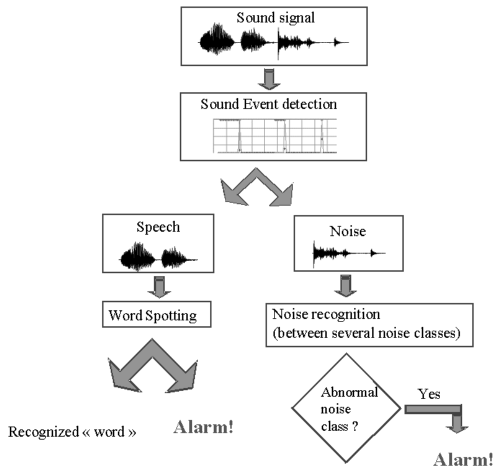


Fig. 3. Real time Display on the User Interface.

3.2. Sound activity monitoring

The sound event detection and classification are complex tasks since the audio signals are not clean and the everyday life sounds are extremely diverse. This system makes a two-step analysis: firstly a sound event detection is made and secondly a sound classification. In the first step, signals from 5 channels are used to detect events and to localize the sound source. An event detected by the first step initiates the second step which begins with a segmentation speech/noise. If a speech has been detected, a Word Spotting system is launched in order to identify calls for help, while in the noise case a recognition system is started in order to recognize the noise class. The smart audio sensor will send an alarm if the Word Spotting detects a call for help or if the recognized noise class is a distress one. For the moment, the recognition system is not in use and the detected events are classified by a human operator.

Two detection algorithms are proposed : first based on the cross-correlation between 2 analysis windows and second based on the energy error prediction [6]. The results on our test set (2376 audio test files composed of sound event and HIS environmental noise at different **S**ignal to **N**oise **R**atio : 0, 10, 20 and 40dB) are good : 6% of **E**qual **E**rror **R**atio (at SNR greater than 10dB) for Cross-correlation based algorithm and 11% of EER (same SNR) for energy prediction algorithm.



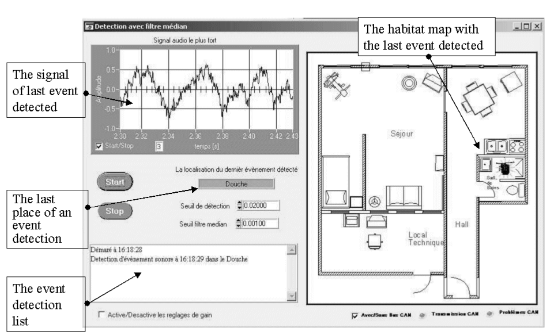
The sound classification method uses a Gaussian Mixture Model (GMM), with 4 gaussian components. The sound recognition system was tested on a 7 classes test sets : dishes sound, door clapping, door lock, glass breaking, screams, telephone ringing and step sound. The best results are obtained with Δ,ΔΔ MFCC parameters and the error rate is about 8.7% in average for all classes

3.3. First steps in data fusion

The sound monitoring system carries out the 5 channels of data acquisition, the sound event detection for all the channels (with localization: room where the sound appeared), the transmission of the information through a CAN bus and the recording of the sound in case of an event detection. On the panel, we show the signal which generated the detected event, its localization (the room) and a list of detected events.

Moreover, the Supervision application, timestamps all the events (messages) as soon as they appear and saves them in a XML format file that constitutes a database :

<sensor><date>13/01/2003</date><time>11:15:23</time><PS>125</PS><PD>084</PD></sensor>
<sensor><date>13/01/2003</date><time>11:25:12</time><entry>bathroom</entry></sensor>
<sensor><date>13/01/2003</date><time>11:27:56</time><weight>68.2kg</weight></sensor>
<sensor><date>13/01/2003</date><time>11:28:56</time><audio>Dishes sounds(90% confidence) in kitchen</audio></sensor>



4. Conclusions and perspectives

This work demonstrates a straightforward implementation of a home health monitoring system, based on an industrial standard, the CAN network. The interconnection between sensors and actuators is performed with a unique telephone pair cable distributed around the apartment and a second pair distribute a low level DC voltage. A wireless connection to ambulatory sensors is also performed with a RF modem (868 MHz) connected to the CAN board. The HIS has been implemented and tested in a real apartment build up within our laboratory.

In this paper we have, also, presented a smart audio sensor which analyses multiple audio channels in order to detect sound events and to recognize the noise class helping a medical telemonitoring system. The smart sensor is composed for the moment by a data acquisition card and a PC. The present results of detection are good. The overall costs are reasonable: the inexpensive SmartCAN authorizes the connection of commercially available cheap sensors. The flexibility of this design also authorises the Plug and Play addition of new sensors and actuators. The system is now ready for deployment in real conditions.

5. Acknowledgments

This work was supported by the grant 99B0616 from the French Ministry of Research to the project «Technologies de l'Information Intégrées au Service des Soins à Domicile» (TIISSAD). We wish to thank “La Métro” which granted us for the building of the technical platform “HIS”, Atral SA and Atmel France, which supplied respectively the sensors and the RF technology.

This system is, also, a part of the IMAG project "REconnaissance de SItuations de DÉtresse en Habitat Intelligent Santé"(RESIDE-HIS).

References

[1] S. G. Bonner, "Assisted Interactive Dwelling HOUSE," presented at Proc. 3rd TIDE Congress: Technology for Inclusive Design and Equality Improving the Quality of Life for the European Citizen*, 23–25 June, Helsinki, Finland, 1998.*

[2] G. Williams, K. Doughty, and D. A. Bradley, "Distributed intelligent nodes as information filters in advanced telecare systems," presented at Proc. 21st Ann. Int. *Conf. IEEE Engineering in Medicine & Biology Society, Atlanta, 1999.*

[3] J. Demongeot, G. Virone *et al.* “Multi-sensors acquisition, data fusion, knowledge mining and triggering in health smart homes for elderly people,“ *C. R. Biologies 325. Académie des sciences / Editions scientifiques et médicales Elsevier SAS,* pp. 673-682, 2002.

[4] G. Virone *et al.* "A Home Health Information System Based on the CAN Fieldbus," FET'2003 *"5th IFAC International Conference on Fieldbus Systems and their Applications,"* Aveiro, Portugal, July 2003 (in press).

[5] D.Paret, « Le réseau CAN, Controller Area Network » Ed. Paris: Dunod, 1996.

[6] M.Vacher, D. Istrate *et al.* Smart Audio Sensor for Telemedicine, Smart Objects Conferences,pp222-225, Grenoble, May 2003.

[7] National Instruments Corporation, "LabWindows/CVI User Manual"", December 1999.

[8] I.Magrin-Chagnolleau, G.Gravier and R.Blouet, "Overview of the ELISA Consortium Research Activities", 2001: a Speaker Odyssey, pp. 67-72, 2001.